Methane and Abrupt Climate Change

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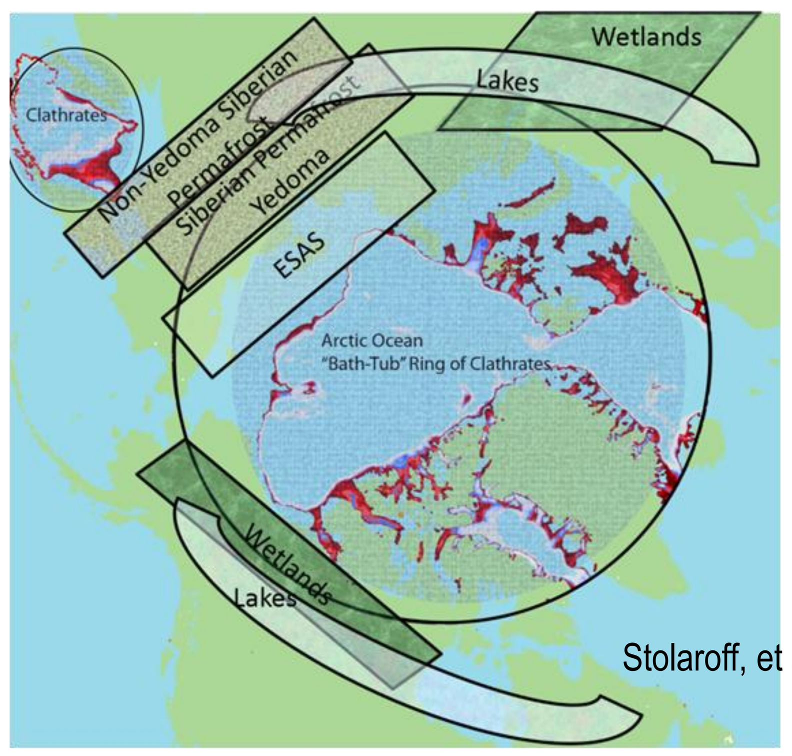
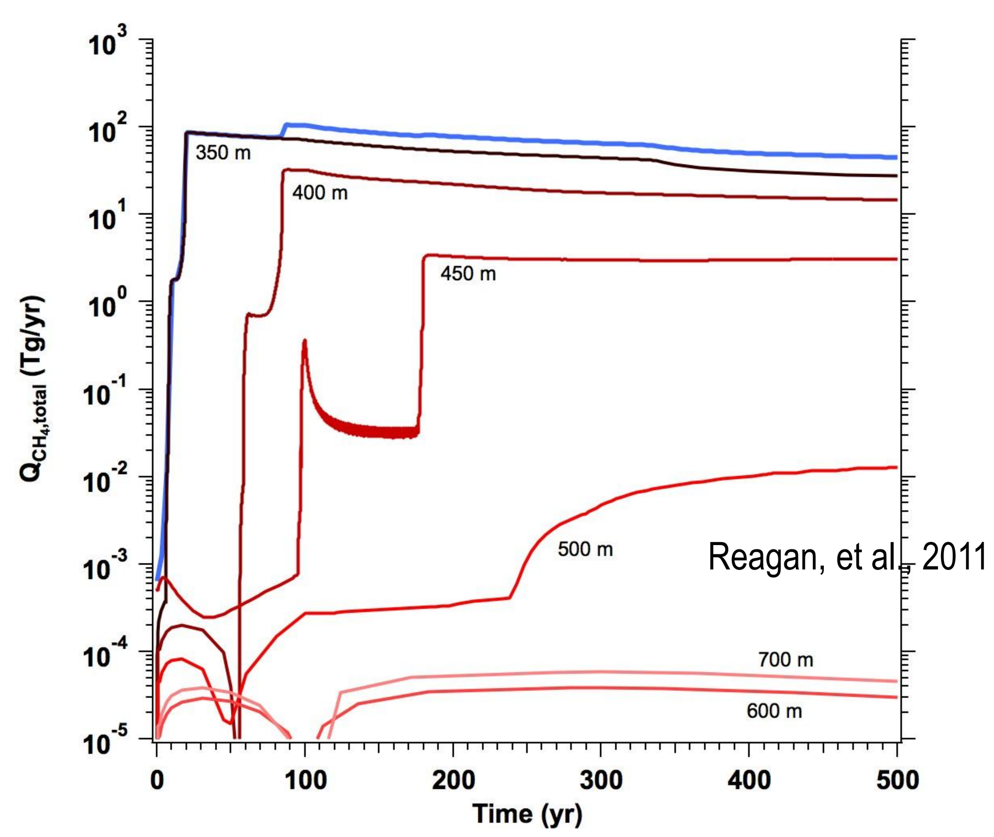
Warming may release methane from large Arctic reservoirs

Expected methane sources due to warming



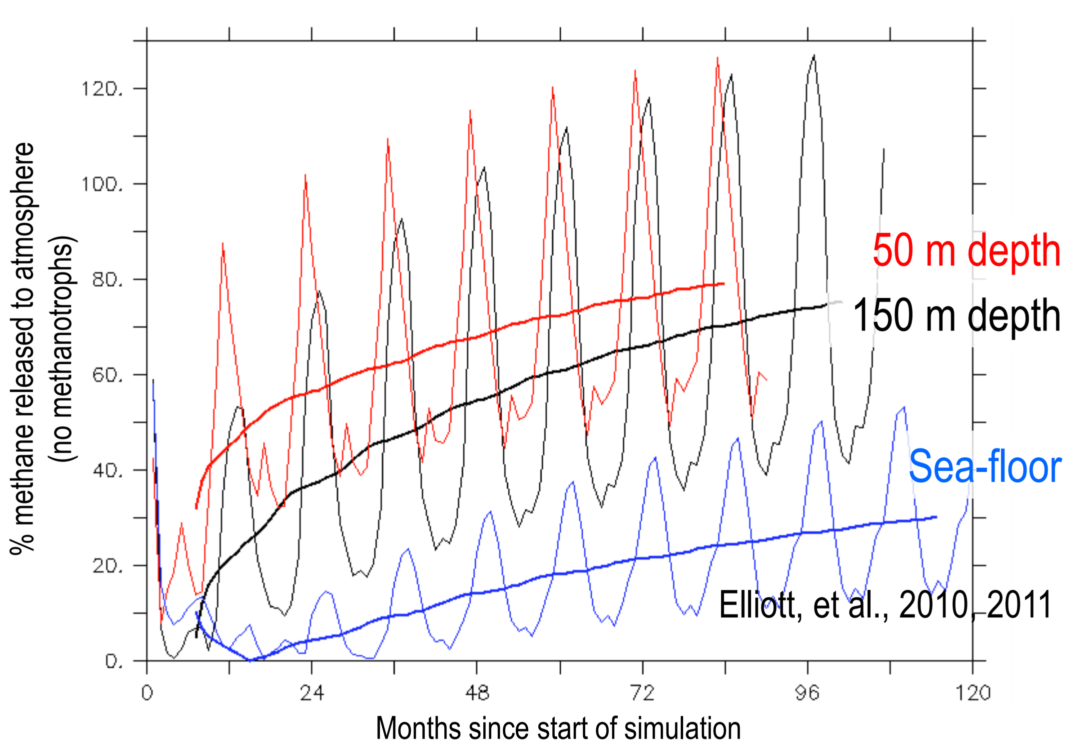
Clathrates are methane locked in a water ice structure.
ESAS = East Siberian Arctic Shelf (methane under submerged permafrost)

Onset of Clathrate emissions expected to be abrupt



This is the sediment response to a temperature ramp of 5K for 100 years.
This emission rate is ~20% of global methane emissions.
Most of the emission comes from 300-400m depth.

Fraction of methane that passes through ocean is uncertain, but could be large



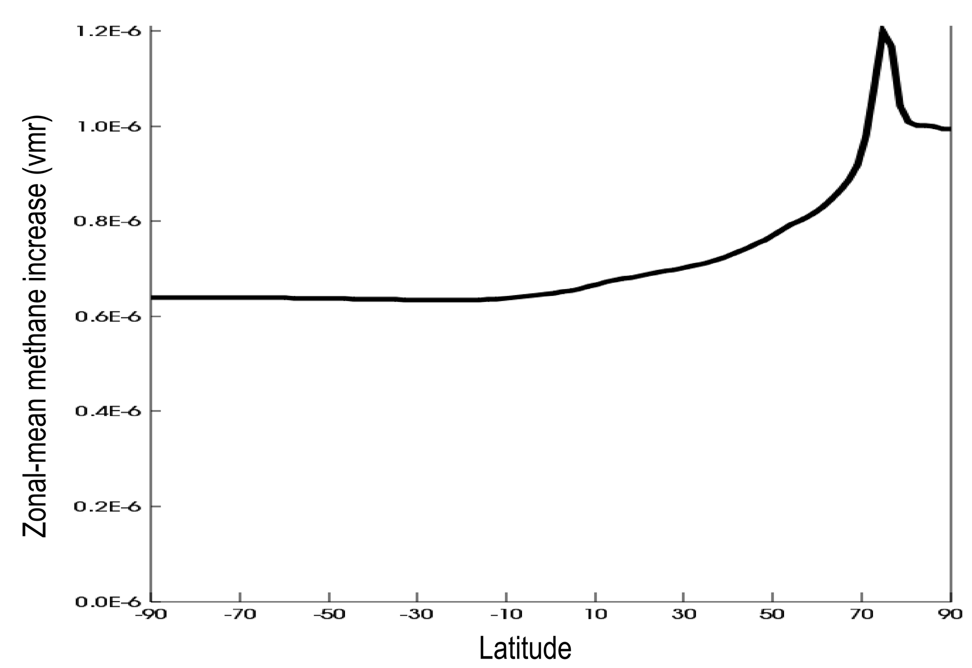
Methane is consumed in the ocean by methanotrophs.
But, bubble plumes may inject methane to upper ocean levels which will allow faster release to the atmosphere.

Clathrate methane emission scenario changes mean climate

We developed a chemistry-climate version of CESM

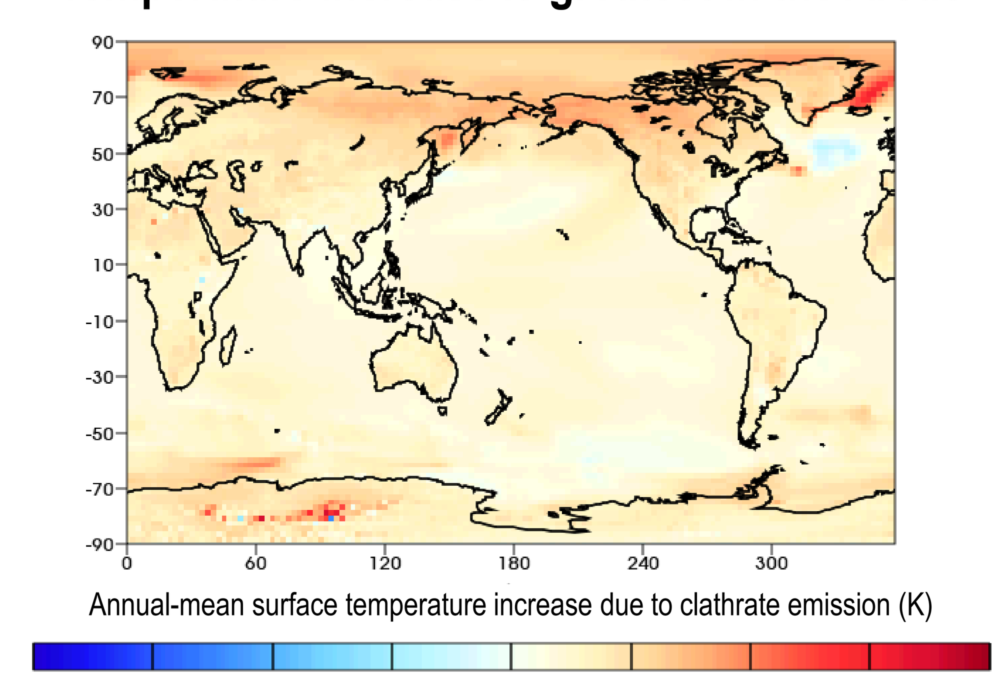
We added a fast chemical mechanism to CESM that is designed to handle methane . We simulated over 400 years (after spinup) under present-day conditions with, and without, the clathrate emissions. We used an active ocean to see the coupled chemistry-climate response.

Methane conc. increases 30-60% non-uniformly



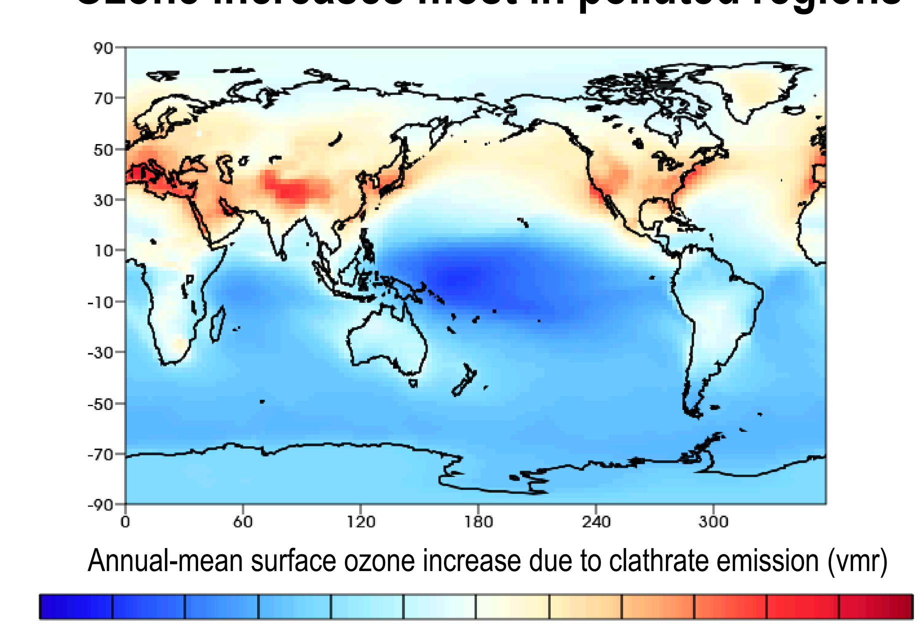
Note that methane suppresses the specie that destroys it, so a 20% emission increase produces over 30% methane concentration increase.

Temperature increase is greatest in the Arctic



The Arctic warming appears to be larger than would be expected for a uniform greenhouse gas. However, the internal variability in the Arctic is great, and the simulations to confirm this are under way.

Ozone increases most in polluted regions



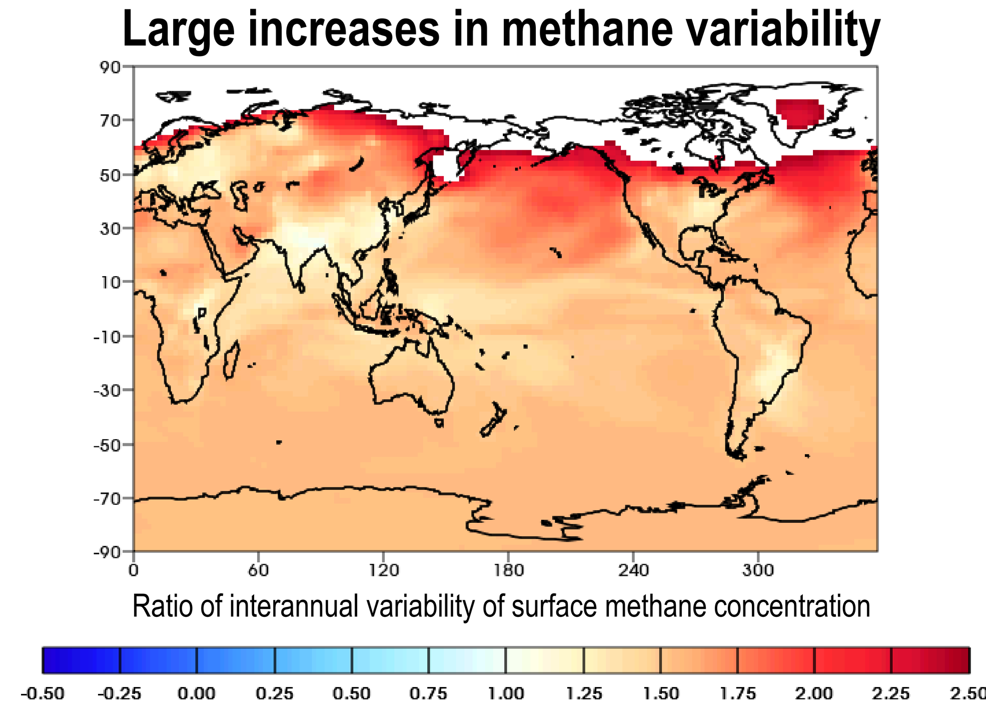
Methane is an important precursor for chemical smog, and the clathrate emissions increase ozone concentrations by ~5ppb in polluted regions. This would cause many regions to exceed EPA pollution limits.

Clathrate methane emission scenario changes variability

Changes in variability with and without clathrate emission is significant for CH_4 & O_3

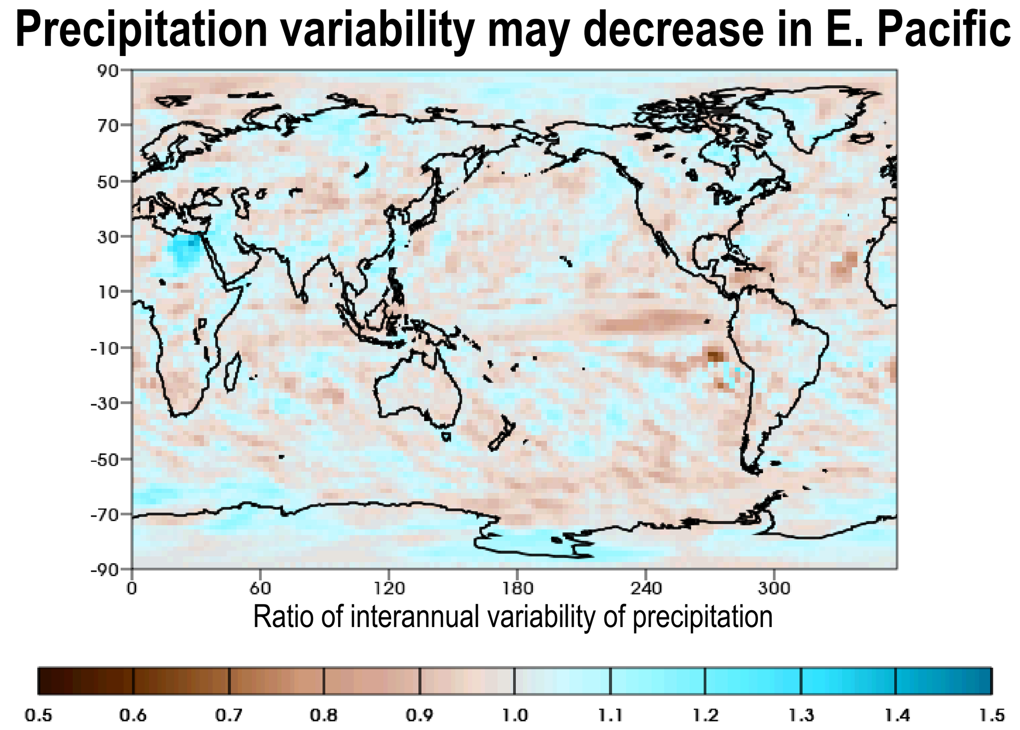
The uncertainty in a sample standard deviation is sigma/sqrt(2n) for independent samples. Hence, the uncertainty in the ratio of two similar standard deviations is 1/sqrt(n). Hence, for a 400 year run the uncertainty in the ratio is ~0.05 (1-sigma) times any correction for autocorrelation.

Large increases in methane variability



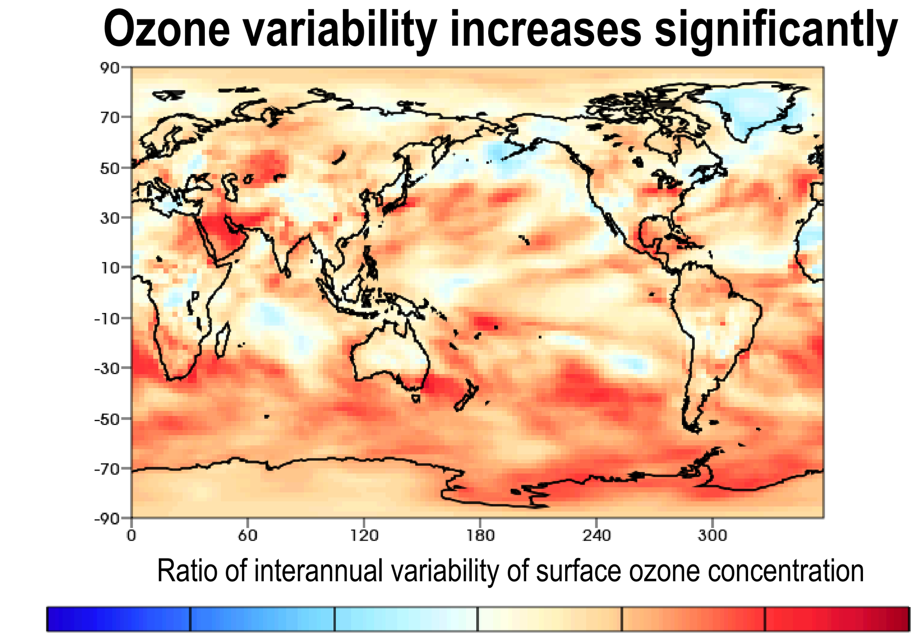
The methane variability is presumably a result of synoptic variability in the dispersion of the methane emissions.

Precipitation variability may decrease in E. Pacific



The interannual variability in precipitation is generally large, so there is a lot of spatial noise in the ratio. One feature that may be robust is the decrease in variability in the El Nino cold tongue. This is usually a dry region in the model, which sees a notable increase in precipitation with the extra methane. The reason is not yet clear.

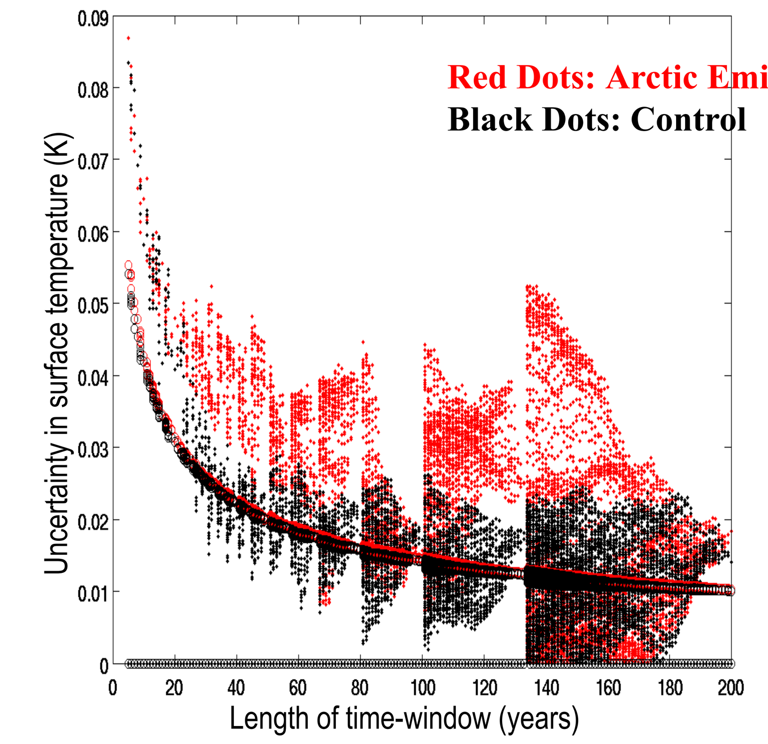
Ozone variability increases significantly



The increase in ozone variability is presumably driven by the methane variability. This increase in variability may increase the number of air-quality exceedances which are based on an 8-hour standard.

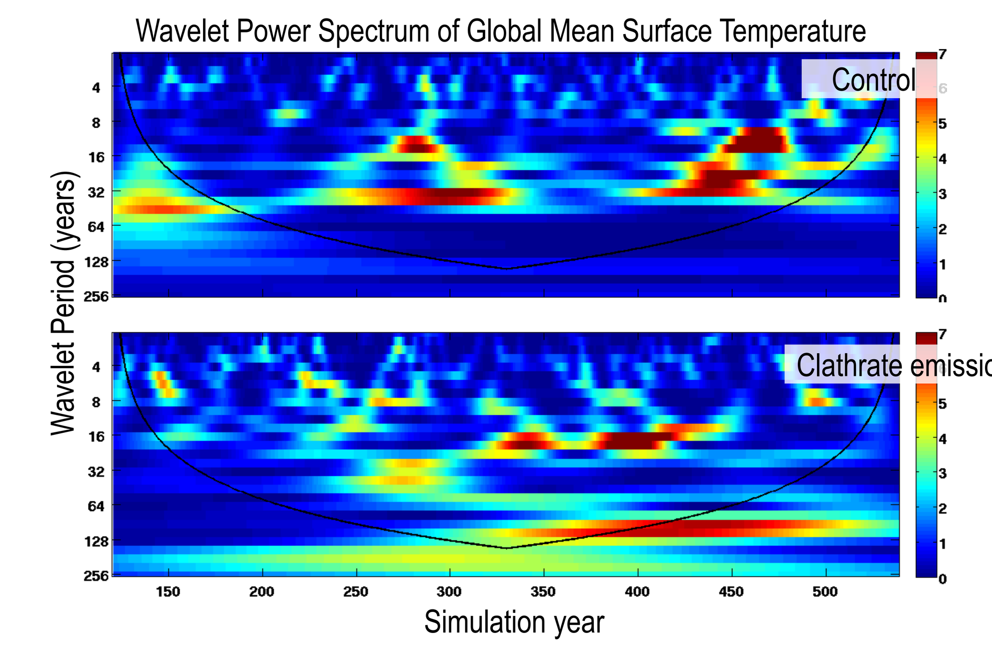
Long-timescale variability is also increased with clathrate emissions

Variability in 20+ year means is almost doubled



The dots are the variability in the means of each time window of the specified length within the 400 year simulation (with different starting years when possible). The circles are the standard error formula without any autocorrelation correction.

Long-term variability increase in wavelet spectra too



There is a definite increase in the wavelet power for 40+ year periods. The cause of these variability increases is unclear: it may be related to interactions of the long methane lifetime with long climate modes.

Future plans

- Couple our atmospheric methane model to ocean and permafrost methane codes.
- Determine emission amplification factors, *ie* the amount of extra methane released due to the warming from the original methane emission (cross-amplification between reservoirs will also occur).
- Assess the likelihood of runaway warming (aka, the clathrate gun).
- Participate in future methane related model intercomparisons (we participated in the Atmospheric Chemistry-Climate Model Intercomparison Project (ACCMIP), which helped confirm and debug our model chemical behavior, and resulted in several papers).

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